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Are consumers satisfied with the use of prosthetic sports feet and the provision process? A mixed-methods study

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ABSTRACT

Background: Special feet connected to a prosthesis, prosthetic sports feet, enable athletes with a lower limb amputation to run. The selection of a prosthetic sports feet is usually based on body weight and preferred sports performance. The selection of a prosthetic sport feet is also based on clinicians who likely have limited experience due to a small number of athletes with a lower limb amputation.

Hypothesis: Athletes with a lower limb amputation are not satisfied with the use and service associated with prosthetic sports feet due to a lack of prosthetic sports feet provision guidelines, poorer function of prosthetic sports feet compared to the anatomical foot and ankle, and limited experience of clinicians.

Evaluation of hypothesis: A mixed-methods study in 16 athletes with a lower limb amputation using a prosthetic sport foot from Össur or Otto Bock, included semi-structured interviews and quantitative analysis. Three dimensions of prosthetic sports feet were investigated: 1) use, 2) provision process, and 3) cosmetics. Qualitative data were analyzed to identify factors influencing consumer satisfaction. Quantitative data were analyzed to investigate satisfaction and perceived relative importance of the dimensions.

Results: Participants were satisfied with the prosthetic sports feet use. However, they were not satisfied with the process prior to provision. The prosthetic sport feet use was perceived as the most important dimension. Sports performance was the critical element in the prosthetic sports feet use and was influenced by stability, confidence and fear, safety, focus, energy return, and comfort. Cosmetics were unimportant. Motivation to purchase the prosthetic sports feet was the key element for the prosthetic sports foot acquisition. Satisfaction about the process prior to provision was negatively influenced by poor support of professionals during rehabilitation, the complexity and duration of the purchase process, and lack of information and accessibility of prosthetic sports feet.

Conclusion: The most important dimension of the prosthetic sports feet was its use, which was directly influenced by performance. To further increase the satisfaction with prosthetic sports feet, clinicians should establish how to meet the desired sports performance level of athletes with a lower limb amputation. Improving the process prior to the provision process may increase satisfaction. We suggest increasing the support of professionals during rehabilitation and training through cooperation between involved services, organizing prosthetic sports feet try-out sessions, and increase the accessibility of the prosthetic sports feet. In this way, individuals with a lower limb amputation may become and stay more physically active and participate in sports.

Background

A limb amputation greatly impacts the physical and psychosocial functioning of an individual [1]. As a result of co-morbidities, the physical condition of a person with a lower limb amputation (LLA) is often poor before a LLA. The physical condition deteriorates even further after a LLA because of an increased level of sedentariness and a lack of exercise [2,3]. For persons with a LLA, sports participation reduces pain, fatigue, and the risk of depression or co-morbidities, while it improves overall health and social contact [2–5]. Still, only a small percentage (± 30%) of individuals with a LLA participate in sports compared to healthy adults (± 60%) [6]. For athletes with a LLA,

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different types of prosthetic sports feet applicable for different sports branches, have been developed [7].

Prosthetic sports feet offer biomechanical advantages, particularly in sports involving running [7–10]. The Flex foot was developed in the 1980s and was seen in Paralympic Games in 1988 [7,11]. With an increase in the speed of running, heel is not used [7,8], thus, carbon fiber prosthetic sports feet for sprinting with various levels of stiffness have been designed to be running on the toes with varied stiffness [7,11,12]. These prosthetic sports feet are usually classified as either C or J shape, and offer spring-like nature of running [7,11]. For athletes with a transfemoral amputation, a prosthetic sports foot can be attached to the shank and socket without a knee joint component for long-distance running [13]. Wearing a shoe is optional; hence the appearance of the prosthetic side is often quite different from that of the sound side.

In general, satisfaction with prosthesis can be affected by its use, property or appearance [14]. Several models of prosthetic sports feet are now sold in the market, but these passive carbon fiber prosthetic sports feet have more or less similar in design since the 1990s [7,15]. Though prosthetic sports feet are designed to mimic running, none of them can outperform the able-bodied foot [7,10,16]. Manufacturers of prosthetic sports feet provide stiffness categories that are used for prosthetic sports feet selection; however stiffness categories vary between manufacturers [12]. User's dimensions including weight, running speed, shapes of the foot should be taken into account when choosing prosthetic sports feet with a certain stiffness [12,17].

Because of a small number of athletes with a LLA, most clinicians are likely to have limited clinical experience in providing prosthetic sports feet. Additionally, stiffness categories of prosthetic sports feet are not based on a standardized unit of stiffness but diverse categories given by manufacturers. None of prosthetic sports feet is as efficient as the anatomical foot and ankle [7,10,16]. Consequently, consumers may receive prosthetic sports feet that do not match their desired performance goals and may be dissatisfied with their prosthetic sports feet and services. Studying the satisfaction of athletes with a LLA can be used for improving prosthetic sports feet applications and the provision process. This mixed-methods study aimed to explore consumer satisfaction with prosthetic sports feet and the relative importance of different dimensions regarding prosthetic sports feet.

Hypothesis

We hypothesized that athletes with a LLA are not satisfied with the use and service associated with prosthetic sports feet. Therefore, we investigated three dimensions of prosthetic sports feet: 1) use, 2) provision process and delivered services, and 3) cosmetics and comments of outsiders regarding prosthetic sports feet.

Methods

The medical ethical committee of the University Medical Center Groningen was informed about this research and replied that there was no need for formal approval (METc 11.104976). All participants signed written informed consent prior to participation.

Participants

Athletes with a LLA using prosthetic sports feet of either Össur or Otto Bock manufacturers were recruited through orthopaedic workshops providing these feet. The orthopaedic workshops invited potential participants by a letter, which detailed general information about the study, an informed consent form, and a response envelope. For this study, participants had to be 18 years or older, had previously undergone a LLA, have a full understanding of Dutch language, and be currently using a prosthetic sports foot from Össur or Otto Bock for sports participation prior to the start of the study. Participants were recruited until data saturation had occurred indicated by no new themes occurred from interviews.

Qualitative data

Qualitative data were obtained through semi-structured interviews (AA). All interviews were audiotaped. Each interview focused on three dimensions. Firstly, participants were asked to specify the characteristics of prosthetic sports feet that they believed were most important and to what extent these characteristics satisfied their use with the prosthetic sports foot. Secondly, participants were asked to give their opinion about the role of the professionals, physical therapist, rehabilitation physician, prosthetist, trainer, and feet manufacturer, prior to and during the provision process, as well as their satisfaction with services and delivery. Thirdly, participants were asked how cosmetics and comments of outsiders about prosthetic sports feet mattered to them and how it influenced use of the prosthetic sports feet. Finally, participants were asked whether their experiences with the above-mentioned dimensions had met their expectations and whether they had specific suggestions that could improve prosthetic sports feet or the provision process.

Quantitative data

To quantify satisfaction with use of the prosthetic sports foot and its provision process, the Dutch version of Quebec User Evaluation of Satisfaction with assistive Technology (D-QUEST 2.0) was used [18]. This questionnaire assesses consumer satisfaction using 12 items with a five-point scale (range; 1 = very dissatisfied to 5 = very satisfied). Eight items focus on satisfaction with the assistive device: size, weight, adjustment possibilities, safety, durability, ease of use, comfort, and effectiveness. The total score is converted to a range from 1 to 5. Four items focus on satisfaction with the provision process: delivery process, repairs and maintenance, professionalism of service, and service after delivery. The total score is converted to a range from 1 to 5. Higher score indicates greater satisfaction. Cronbach's alpha is 0.89, and 0.83 and associations (ρ) between satisfaction scores of the D-QUEST 2.0 and problem-solving ability were 0.38 and 0.23 respectively) [18].

The Schedule for Individual Quality of Life, Direct Weighting Procedure (SEIQoL-DW) [19] was used to evaluate the relative importance of use of the prosthetic sports feet, provision process, and cosmetics. SEIQoL-DW allows individuals to identify which domain, use, provision process, and cosmetics, is important for them and how they perceive the relative importance of these domains [19]. SEIQoL-DW property has not been tested in people with a LLA [20]. SEIQOL-DW consists of a circle with three concentric stacked discs. Each disc represents one of the three dimensions. The starting position was 120° per disc. The discs can be rotated by the participants over each other so that it forms a dynamic pie chart, in which the relative size of each disc represents the perceived importance per dimension. The size of each disc was measured in degrees by means of a scale on the outside rim. Degrees were thereafter transformed into percentages, with a full circumference of 360° equaling 100%.

Data analysis

Qualitative data

Interviews were transcribed verbatim, anonymized and given a random number. Data analysis was based on qualitative interpretation, including data familiarization, generation of initial codes, searching for higher-order factors, reviewing factors and codes, and final adjustments (AA, SvP). Progress on conceptualization during these steps was documented (SvP). For each of the three dimensions, frequently cited concepts were matched. After conceptualization, a third observer (RD) checked four random interviews regarding the concepts found. Discrepancies in concepts were discussed (SvP, RD) until consensus was reached. Diagrams were designed to illustrate the relationship between

Table 1
Characteristics of participants (n = 16).

Characteristics	n	%*
Males	10	63
Amputation level:		
-Transtibial	8	50
-Knee disarticulation	6	38
-Transfemoral	2	13
Cause of amputation:		
-Cancer	5	31
-Trauma	5	31
-Infection	2	12
-Vascular	2	12
-Other	2	12
Levels of athletes:		
-Recreational athletes	8	50
-Top athletes/ former top athletes	8	50
Sports#:		
-Running	13	81.3
-Long jump	2	12.5
-Throwing the javelin	1	6.3
-Cycling	3	18.8
-Golf	1	6.3
-Tennis	1	6.3
-Ice skating	1	6.3
-Snowboarding	1	6.3
-Obstacle running	1	6.3
	Median	**IQR**
Age in years	37.5	25.8; 46.0
Years of use	3.8	3.0; 8.9
	Mean	**SD**
Satisfaction of prosthetic feet use (D-QUEST 2.0[1])	4.1	0.4
Satisfaction of provision process (D-QUEST 2.0[2])	4.1	0.7
Acceptable personal contribution in euro's	756.3	881.6
Maximal personal contribution in euro's	3125.0	2903.9
Importance (SEIQoL-DW):		
-Prosthetic sport foot use	71.5	16.1
-Provision process	27.1	16.2
-Cosmetics and comments from outsiders	1.4	1.8

D-QUEST 2.0 = Dutch version of Quebec User Evaluation of Satisfaction with assistive Technology, 1 = assistive device part (range 1 to 5), 2 = provision process part (range 1 to 5), SEIQoL-DW = Schedule for Individual Quality of Life, Direct Weighting procedure, IQR = interquartile range, * Due to rounding percentages do not add up to 100. # Some athletes were active in more than one type of sports. SD = standard deviation.

factors per dimension and were verified in the transcribed interviews (PD).

Quantitative data

Descriptive statistics regarding age, sex, level of amputation, acceptable, and maximal personal financial contributions were calculated. D-QUEST 2.0 and SEIQol-DW scores were calculated to compare with the qualitative results.

Results

In total, 16 athletes participated in the study. A majority of participants were males (63%) with a median age of 37.5 years (IQR = 25.8, 46.0). The participants mostly had a transtibial amputation (n = 8). Two main causes of amputation were cancer (31%) and trauma (31%). Participants had used a prosthetic sport foot for a median duration of 3.8 years (IQR = 3.0; 8.9) in nine types of sports, particularly running (n = 13). Half of the participants were top/ former top athletes and another half were recreational athletes with a LLA (Table 1). Levels of athletes or years of prosthetic sports feet used were not associated with satisfaction or SEIQol-DW scores ($p > .05$) (Table A1, Table A2). After 14 interviews, data saturation had occurred and two additional interviews were conducted to confirm data saturation. Factors influencing satisfaction with the use of prosthetic sports feet and provision process were summarized in Figs. 1 and 2. Factors influencing satisfaction with

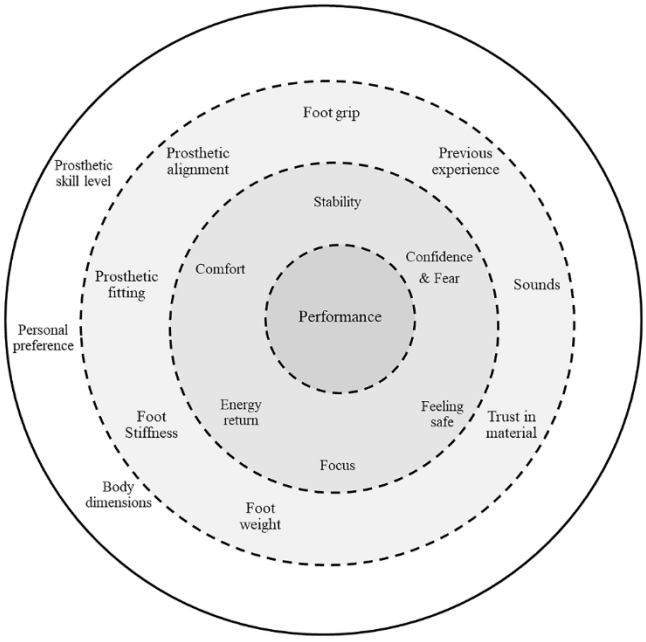

Fig. 1. Representation of factors influencing satisfaction with the prosthetic sports feet use. The innermost circle "performance" is the key factor directly influences the satisfaction with the prosthetic sports feet use. Circles further from the center have less direct influence on satisfaction with the prosthetic sports feet use. All factors in the outer circle directly influence the inner circle. Dashed lines between the circles indicate the inseparable connection between each factor. Within circles, the factors influence each other reciprocally.

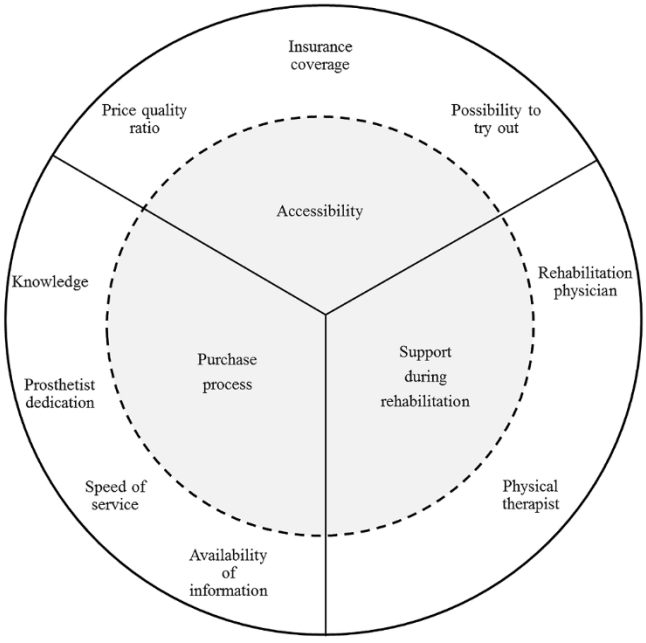

Fig. 2. Representation of factors influencing satisfaction with the prosthetic sports feet provision process. Factors in the outer circle directly influence the inner circle. Factors separated by the solid lines do not seem to be related. Dashed lines between the circles indicate the connections between factors.

cosmetics of the prosthetic sports feet and outsiders' comments about them could not be found because this dimension was absolutely unimportant for all participants (Table 1). Examples of participants' opinions are shown in italics with a participant number in the bracket.

Dimension 1: Factors influencing satisfaction with prosthetic sports feet use

Overall, participants were quite satisfied (mean score 4.1) with the use of their prosthetic sports foot (Table 1), *"Running feels fantastic… it feels like I am running on a trampoline"* (14). Additionally, use of their prosthetic sports foot was the most important dimension for participants, the mean SEIQoL-DW score was 71.5% (SD = 16.1) (Table 1).

Expectations prior to use of their prosthetic sports foot differed among participants. In general, one either expected an improvement of performance or had no expectations at all. After the first use, all participants were impressed with the increase in the energy return of their prosthetic sports foot compared to the daily prosthetic foot. Personal requests concerning the foot were mainly about adaptations regarding its comfort, energy return, or stability to improve sports performance.

Performance

Performance was the single most important factor for using the prosthetic sports feet, though the level of performance was quite diverse in range, from 'being able to participate in sports' to 'improving personal records and achieving goals.' Six factors influencing performance were: stability, confidence and fear, feeling safe, focus, energy return, and comfort. These factors were interrelated and influenced by each other (Fig. 1).

Stability. The stability of prosthetic sports feet was influenced by prosthetic alignment, fitting, and grip. Alignment is very subjective and, according to participants, adjustments of only millimeters had large effects, *"If the alignment is incorrect, you will definitely lose much energy, and it will probably be returned in wrong directions."* (3). The optimal alignment depended on a (personal) trade-off between energy return and comfort of prosthetic sports feet. The alignment was also closely related to confidence and fear, *"… a good alignment can increase your confidence…"* (1). Poor-fitting reduced stability and comfort, which in turn had a negative influence on performance. In general, participants were satisfied with the fitting of the socket and did not mention residual limb irritations or wound development due to the use of a prosthetic sports foot. According to participants, the grip of the prosthetic sports feet on the ground increased stability and feeling of safety, *"I am currently using a sole, … it just gives me so much grip… thus it feels safer."* (11). Despite high satisfaction when using prosthetic sports feet on athletic courts, participants mentioned that running on other surfaces (e.g., off- or on-road) was less satisfactory, because of poor grip. *"… the carbon plate does not have any grip on the ground… manufacturers lack the experience in making soles, and there is no existing soles assortment yet."* (5). At the time of research, one type of outdoor sole was available, which had a click system to attach to the prosthetic sports foot. However, almost all participants attempted to increase grip by gluing soles from running shoes to their prosthetic sports feet. One major disadvantage of gluing a sole to the carbon plate was that, once attached, removal was impossible. Participants were then unable to run on athletic courts and outside these courts unless they had several prosthetic sports feet.

Confidence and fear. Confidence and fear were mentioned as one factor since they were reciprocal and depended on the same group of factors. Confidence and fear were mostly influenced by previous experiences and knee prosthetic sounds. Previous victories increased confidence, whereas falls decreased confidence and increased fear. Audible sounds of footsteps or that of a sports prosthetic knee click adapter increased confidence since these sounds provided auditory feedback during running. Confidence and fear were also influenced by trust in the material, stability, energy return, and safety. After a negative experience (such as breaking of the carbon plate), participants generally felt less confident, less safe, and less stable when using prosthetic sports feet. As a result, participants did not dare to fully rely on their prosthetic sports foot anymore. A consequence of this experience was a reduced load on their prosthetic sports foot translating to a reduced energy return, which in turn reduced performance and induced an inefficient gait.

Feeling safe. Feeling safe on prosthetic sports feet depended on material trust, *"It is very important to dare to rely on the material,…, otherwise you will keep being aware of the fact that you wear a prosthetic sports foot … If you trust your material the, prosthetic sports foot will become part of you."* (15). All participants felt safe using their prosthetic sports foot because they trusted the material. *"Feeling safe will increase your confidence, which in turn will help you reaching your new goals."* (13). Still, feeling safe did not mean totally confident and no fear because other factors such as previous experiences, alignment, or audible sounds also influenced confidence.

Focus. The focus during prosthetic sports foot use appeared to be an important aspect of sports performance. Participants focused on auditory, visual and/or proprioceptive feedback from the environment or the prosthetic sports feet. Increased focus led to an increased feeling of safety during running.

Energy return. Sports performance was influenced dramatically by the energy return… *"As an athlete, you would like to have maximum efficiency… [of energy return] from prosthetic sports foot."* (1), *"Without energy return, nobody is able to walk or run."* (12). Energy return depended on prosthetic sports foot weight and stiffness. The optimal prosthetic sports foot weight was determined by personal preferences and body dimensions, such as body weight and height. However, some athletes considered using a prosthetic sports foot with a weight class that did not match their weight class. Heavier prosthetic sports feet felt more comfortable and safe, but returned less energy, compared to the lighter ones. Most participants preferred prosthetic sports feet to be as light as possible in order to increase speed, *"The lighter, the better,… but only if it provides enough stability."* (14). However, reducing the weight of prosthetic sports feet decreased feedback and proprioception, *"…it is harder to estimate where your prosthetic sports foot is in the environment."* (1) and reduced stability, *"…the more energy returned, the harder to control it."* (1). Therefore, it seemed that a lighter prosthetic sports foot required more muscle control to compensate for the decreased stability.

For an individual, the optimal stiffness of prosthetic sports foot, the way prosthetic sports foot bent and stored energy when forces of the body acted upon it during stance phase, seemed to depend on body dimensions, such as body weight, height and leg-length and level of amputation, as well as level of prosthetic skill. Participants found that a stiffer prosthetic sports foot would result in increased energy return, but would feel less comfortable and safe, *"A stiffer prosthetic sports foot returns more energy… so it enables you to run faster or jump further."* (2). Participants preferred a less safe and comfortable, stiffer prosthetic sports foot in favor of increased energy return to improve personal records. Light and stiff prosthetic sports feet were mostly used by short-distance athletes, while heavier and less stiff prosthetic sports feet were mostly used in long-distance athletes.

Comfort. Comfort was related to the connection between the socket and residual limb. Comfort was at its best when stump load was as low as possible, which was realized through optimal fitting and alignment of the socket and prosthesis. Comfort was also related to the weight and stiffness of prosthetic sports feet. As already mentioned, prosthetic sports feet must have a certain weight and stiffness to be comfortable. Consequently, comfort was bi-directionally related to stability and energy return. *"Stiffness of prosthetic sports foot partly determines the comfort of the device: less stiffness indicates more comfort, but also less stability… Most important in choosing a specific prosthetic sports foot is the amount of energy returned, which depends on the stiffness and weight ….."* (7).

Dimension 2: Factors influencing satisfaction with provision process and delivered services

The mean satisfaction with and importance of the provision process with the prosthetic sports feet were 4.1 (SD = 0.7) and 27.1% (SD = 16.2), respectively (Table 1).

Motivation to purchase

The single most important factor in acquiring the prosthetic sports feet was the motivation to purchase prosthetic sports feet of the athletes. Satisfaction with the provision process was influenced by support during rehabilitation, accessibility of prosthetic sports feet, and the purchase process (Fig. 2). These three factors were independent of each other.

Support during rehabilitation. Support during and after rehabilitation, provided by physical therapists and rehabilitation physicians, was perceived as unsatisfactorily. Physical therapists and rehabilitation physicians often seemed skeptical concerning prosthetic sports performance and sometimes advised against it. Participants felt demotivated by these individuals lack of encouragement in prosthetic sports participation.

Accessibility. The accessibility of prosthetic sports feet seemed to depend on a price-quality ratio, insurance coverage, and possibilities to try prosthetic sports feet. In general, participants found prosthetic sports feet too expensive relative to their durability. However, they were willing to contribute financially to the purchase of a prosthetic sports foot, though the amount varied highly among participants (Table 1). According to participants, compensation from health care insurance companies or the government was essential in order to make the device affordable, especially for non-elite athletes. However, the request of compensation was generally rejected by insurance companies and the process of allocation was experienced as a dragging process, *"… from what I heard, I already expected the process (allocation of compensation) to be a long-lasting, exhausting process."* (3).

Furthermore, participants were dissatisfied with the absence of a well-defined structure on the procedures of compensation from health care insurance companies in the Netherlands, *"… it is pure arbitrariness whether they [the government or other parties] will compensate for the device…"* (1). These factors restricted the accessibility of prosthetic sports feet. Participants were displeased by the fact that the government strictly and fully compensates sports wheelchairs, while compensation for sports prostheses is inconsistent and dependent upon the province a user resides in. On some occasions, manufacturers and prosthetists donated participants second-handed material. According to participants, it all comes down to being lucky, *"If, by chance, you meet the right persons, they help you and give you some materials for free."* (5). Often, elite athletes received their prosthetic sports feet from manufacturers for free.

Although sports participation is included in most current rehabilitation programs, participants generally were not able to try any prosthetic sports feet during the rehabilitation. Participants mentioned that the accessibility of the prosthetic sports feet could be improved by organizing specific test days during the rehabilitation. These days would enable athletes with a LLA to get acquainted with sports prosthetic devices and try out different types of prosthetic sports feet, prior to purchase. *"… but what matters most is that it is actually impossible to try out different types of prosthetic sports feet and find out which type fits you best."* (13). Some participants speculated that organizing test days would lower barriers for those who consider using a prosthetic sports foot but did not know what to expect from such a foot. Those people are now held back by the high costs of prosthetic sports feet.

Process of purchase. During the process of purchase, the role of prosthetists and trainers was valued as most useful, while that of physical therapists and rehabilitation physicians was considered least useful. The process of purchase depended, according to participants, on knowledge, availability of information ahead of purchase, speed of service, and prosthetists' dedication.

Participants mentioned two types of knowledge sharing: within professionals and between professionals. According to the participants, most prosthetists lacked sufficient knowledge about fitting and alignment of prosthetic sports feet and seemed unable to make recommendations about different types of feet. Moreover, participants experienced no collaboration between professionals, *"…., a manufacturer should explain the characteristics of the prosthetic sports foot to the prosthetist… together they bring knowledge to a higher level."* (7).

Information about the purchase process in advance seemed hardly obtainable, and physical therapists seemed unable to refer participants to the correct professionals. No clear overview exists that guided participants prior to and during the provision process. *"If you are really handy, you can find out which types of feet are available… however, you have to search the internet systematically … it is really difficult."* (10). Participants mentioned that they would benefit from overviews concerning information about different types of prosthetic sports feet and contacts with prosthetic sports feet related services.

In addition, participants were dissatisfied with the speed of service of the manufacturer, the request for compensation and delivery process, because of the long-lasting administrative processes of insurance companies, rehabilitation physicians, or manufacturers. *"For me, my prosthetic sports foot is my life,… for professionals, it is just their job. They close the door after five o'clock. It makes me feel helpless when it takes so long to get a new prosthetic sports foot."* (1). However, participants were generally satisfied with the speed of service from prosthetists and found certain prosthetists very dedicated to their jobs, mostly because they were allowed to contact their prosthetists any hour of the day.

Dimension 3: Factors influencing satisfaction with cosmetics and comments of outsiders

In most cases, athletes were satisfied with the appearance of their prosthetic sports foot and described it as *"a futuristic look"* (1). This look did not influence the participants' prosthetic sports foot use. In fact, they found it matching their appearance as disabled sports participating individuals. Despite the satisfaction with the cosmetics of the prosthetic sports foot, participants found the appearance of the prosthetic sports foot unimportant (Table 1). Negative comments of outsiders did not influence participants' use or purchase of the prosthetic sports foot. Comments were generally positive and were experienced as stimulating.

Discussion

Based on the D-QUEST scores participants seemed quite satisfied with the use of prosthetic sports feet and the provision process. The most important dimension of prosthetic sports feet was the use. Cosmetics and comments from others were unimportant. The satisfaction with prosthetic sports feet use was predominantly based on the ability to perform sports. Motivation to purchase a prosthetic sports foot was the most important factor for the consumers to request for the prosthetic sports foot prior to the provision process.

Most factors associated with satisfaction with prosthetic sports feet were related to sports performance. Focus, confidence, and fear were not directly related to use but, were required for optimal performance and thus did influence, as a prerequisite, the consumer satisfaction with the device. All factors were strongly interrelated. To reach optimal performance, optimization of all factors should thus be strived for. Because most athletes with a LLA were satisfied with the use and functionality of prosthetic sports feet, adjustments do not seem essential and should not be considered as a first priority to increase the use of and satisfaction with prosthetic sports feet.

According to participants, weight and stiffness of prosthetic sports feet altered energy return and stability. Additionally, alignment, fitting, and grip affected stability. From research, it is known that shape, weight, and alignment of prosthetic sports feet can change the center of mass and can affect aspects of running such as speed, range of motion, and limb symmetry [7]. Lighter prosthetic sports feet may reduce the energy cost of athletes, but it is unclear this reduction affects running performance [7,21]. Previously, the effects of different settings in heights, angles, and masses attached to prosthetic sports feet were tested in two prosthetic sports foot models from the same manufacturer [22]. No differences were found in ground reaction peak, deflection, and contact and flight times between the two models [22]. It was suggested that setting does not influence the properties of prosthetic sports feet, and setting is likely dependent upon preference of the athletes with a LLA [22].

Prosthetic sports feet with a higher stiffness have a higher natural frequency compared to less stiff prosthetic sports feet [17]. When bouncing frequency matches with the prosthetic sports foot natural frequency, the bouncing action is amplified with less effort. This effect has been described as a trampoline effect [17], and is reported by participants. Prosthetic sports foot selection based on the individual's body weight may not give matched frequencies. However, if athletes with a LLA can adapt their running frequency to, or close to the natural frequency of that prosthetic sports foot, the trampoline effect can be achieved [17], and satisfaction may increase.

Some athletes with a LLA felt less safe when stiffness increases because of reduced stability. When a foot stiffness decreases, the prosthetic foot support increases during walking [23]. Dynamic stability in running of able-bodied individuals depends on the ability to adjust their leg stiffness quickly on varied and unpredictable terrains [24]. In amputees, leg stiffness is a combination of the angle swept through an arc during the stance phase and contact length and is determined by the ability of prosthetic sports foot to withstand deformations [25]. Prosthetic sports foot models with the highest stiffness yield the lowest deformation and shortest contact time [22]. When the running speed increases, the vertical ground reaction forces increase and hence the increase in prosthetic sports foot compression and contact time [25]. But a particular stiffness of a prosthetic sports foot may be too high for one person and too low for another with the same body weight if they run with different speeds or have different abilities to compress the prosthetic sports foot. Since athletes with a LLA cannot adjust stiffness of prosthetic sports feet, the ability to tune the running speed could affect the perceived stiffness of the prosthetic sports foot.

Results concerning satisfaction with daily prostheses are not in line with the results of the current study. For daily prostheses, the overall satisfaction and satisfaction concerning the weight, the cosmetics and functionality were moderate [26,27]. Moreover, the most important factor determining satisfaction for daily prostheses seemed to be the degree in which the shape of the prosthesis matched the sound limb [28]. The differences in satisfaction with a daily prosthesis and a prosthetic sports foot clearly depict that the expectations concerning the prosthesis depend on the goal and reason to purchase. Cosmetics predominantly determine satisfaction with a daily prosthesis, whereas function is most important for satisfaction with a prosthetic sports foot.

Athletes with a LLA were quite satisfied with the provision process based on the satisfaction scores despite their negative feedback. Because the satisfaction of the provision process was calculated from the four items of the delivery process, repairs and maintenance, professionalism of service, and service after delivery, it is possible that in general, they were satisfied with aspects mentioned in the questionnaire but not with the process prior to delivery. The lack of encouragement from rehabilitation professionals regarding sports participation might be explained by the fact that these professionals usually treat persons with a LLA that are older with vascular dysfunctions and deteriorated physical fitness before amputation. These persons generally do not participate in sports after a LLA [2,3]. Consequently, physical therapists and rehabilitation physicians should be more alert to those individuals who seek to participate in prosthetic sports. They should take into account one's background in sports participation, motivation, and body dimensions in order to predict and stimulate one's ability to participate in prosthetic sports during and even after rehabilitation.

Prior to the provision process, information about prosthetic sports feet was scarcely available for athletes with a LLA. The lack of information was partly based on the lack of knowledge of physical therapists, prosthetists, manufacturers and trainers. Strengthening cooperation between these professionals and sharing of information may reduce this problem. Through enhanced cooperation, overviews about various aspects related to prosthetic sports feet can created, which in turn could facilitate the provision process. Such overviews may focus on the characteristics of all types of the prosthetic sports feet and their prices, referrals to prosthetists and other professionals involved in the provision process, data of test days, and a step-by-step description of the provision process.

Lower limb amputees found the accessibility of prosthetic sports feet poor, and different aspects were expected to increase accessibility. Firstly, the procedures of compensation should be adapted to equal and comprehensible procedures for all athletes with a LLA. The current allocation system of compensation was perceived as arbitrary and restrictive to the purchase. In the Netherlands, the allocation of compensation is organized per province resulting in differences in allocation between provinces. Creating a set of standardized nationwide processes concerning the compensation of prosthetic sports feet would assure equal allocation processes among athletes with a LLA.

Moreover, the accessibility of prosthetic sports feet could be increased by introducing the possibility to try-out prosthetic sports, for instance, in rehabilitation programs. This try-out would give athletes with a LLA the opportunity to experiment with different types of prosthetic sports feet and various types of prosthetic sports during rehabilitation. In this way, the choice for a specific type of the prosthetic sports foot does not entirely have to depend on the expertise of one person, but can also be based on previous experiences of the athlete.

Limitations and future research

This study was limited to exploring the satisfaction of the prosthetic sports feet in a small study sample. But despite the small sample size, data saturation was reached. Though previous experience with prostheses or prosthetic sports feet could affect the current prosthetic sports feet satisfaction, we did not record how many prostheses the athletes have had since their LLA. Prosthetic sports feet was the sole topic of this research and future research should explore consumer satisfaction with other prosthetic parts.

Conclusion

Our hypothesis that persons with a LLA are not satisfied with the use of prosthetic sports feet has to be rejected since athletes with a LLA were satisfied with the prosthetic sports feet use. We can partly reject the hypothesis of participants not being satisfied with the provision process based on D-QUEST scores. However, we have doubts about this score since the D-QUEST does not consider all aspects of the provision process. Athletes with a LLA found performance the most important reason for using prosthetic sports feet. Stability, confidence and fear, safety, focus, energy return, and comfort influenced performance directly. The consumers' satisfaction with the provision process could be improved since they experienced poor support during rehabilitation, poor process of purchase, and poor accessibility of prosthetic sports feet. Involved professionals should enhance their cooperation and arrange the prosthetic sports feet try-out sessions in order to improve the experience of athletes with a LLA prior to the provision process.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix 1

Table A1.

Table A1
Satisfaction and importance of prosthetic sports foot, provision process and cosmetics/comments from outsiders rated by recreational athletes and top/ former top athletes with a lower limb amputation.

	Recreational athletes (n = 8)		Top/former top athletes (n = 8)		U	p
	Median	IQR	Median	IQR		
Satisfaction of prosthetic feet use (D-QUEST 2.0[1])	4.1	3.9; 4.5	3.9	3.6; 4.5	23.5	0.382
Satisfaction of provision process (D-QUEST 2.0[2])	4.4	3.2; 4.7	4.2	4.0; 4.7	34.5	0.798
Importance (SEIQoL-DW):						
-Prosthetic sport foot use	71.0	56.0; 84.0	72.5	59.5; 81.0	32.5	1.000
-Provision process	26.5	16.0; 43.0	25.0	16.5; 38.0	31.5	0.959
-Cosmetics and comments from outsiders	0.5	0; 1.0	1.0	0; 4.0	40.0	0.442

D-QUEST 2.0 = Dutch version of Quebec User Evaluation of Satisfaction with assistive Technology, 1 = assistive device part (range 1 to 5), 2 = provision process part (range 1 to 5), SEIQoL-DW = Schedule for Individual Quality of Life, Direct Weighting procedure, IQR = interquartile range. U = Mann- Whitney U test statistic.

Appendix 2

Table A2
Satisfaction and importance of prosthetic sports foot, provision process and cosmetics/comments from outsiders and the relationship with years of prosthetic sports foot use.

	Years of use (n = 15*)	
	r	p
Satisfaction of prosthetic feet use (D-QUEST 2.0[1])	0.483	0.068
Satisfaction of provision process (D-QUEST 2.0[2])	0.062	0.827
Importance (SEIQoL-DW):		
-Prosthetic sport foot use	−0.298	0.281
-Provision process	0.286	0.301
-Cosmetics and comments from outsiders	−0.290	0.294

D-QUEST 2.0 = Dutch version of Quebec User Evaluation of Satisfaction with assistive Technology, 1 = assistive device part (range 1 to 5), 2 = provision process part (range 1 to 5), SEIQoL-DW = Schedule for Individual Quality of Life, Direct Weighting procedure, r = Spearman's correlation coefficient. *Of one participant years of prosthetic sports foot use were not available.

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